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Research Article

Effect of artificial accelerated Aging on Translucency of CAD/CAM HT Zirconia and Reinforced Composite material at Two Different Thicknesses

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Abstract

Background: One of the main goals of dental prosthetics is to achieve a high aesthetic demand for the patient through the selection and production of aesthetic restorations that encourage the use of ceramic and dental-coloured composite resins to mimic the colour and translucency of natural teeth. Objectives**:** Aimed to evaluate the effect of artificial accelerated aging on translucency of two aesthetic materials namely CAD/CAM, HT Zirconia and reinforced composite based materials at two different thicknesses. **Methods:** high translucent zirconia and reinforced CAD/CAM composite. A total of forty disks specimens, shade A2, were prepared from two different CAD/CAM materials and ordered into two groups (n=20) according to type of material. Then each group divided to 2 subgroups according to thickness 0.3 and 0.5mm (n=10). Evaluation of translucency parameter done before and after artificial accelerated ageing for 5 hours in an autoclave at 134°C, 0.2 MPa utilizing a spectrophotometer. The Translucency Parameter (TP) was determined $TP=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$. **Results:** Regardless of thickness, Composite revealed statistically significantly greater mean TP than zirconia (P-value <0.001). Thickness had an impact on the translucency parameter of two materials. Within group comparisons revealed that for each of the two materials, 0.3 mm revealed statistically significantly higher mean TP than 0.5 mm (P-value <0.001). A statistically significant impact of aging on translucency parameter (P-value <0.001) was existing which aging showed statistically significantly decreasing in mean TP for both materials. **Conclusion:** the translucency parameter was significantly affected by type of material, thickness, and aging within the limitations of this study.

Key words: translucency, zirconia, Aging, thickness.

Introduction

One of the main goals of dental prosthetics is to achieve a high aesthetic demand for the patient through the selection and production of aesthetic restorations that encourage the use of ceramic and dental-coloured composite resins to mimic the colour and translucency of natural teeth. This demand prompts manufacturers to provide new materials with improved optical properties. [1] Reinforced CAD/CAM materials are a new CAD-CAM material compared to polycrystalline ceramics and glass-ceramic materials, these materials offer easier milling and adjustment.[3] Documented studies on resin-based ceramics have revealed modulus, hardness and fracture toughness similar to dentin and enamel.[4] Zirconia-based ceramics are commonly utilised in dentistry because of their superior mechanical properties over glass-ceramics. Yttria-stabilized tetragonal zirconia monolithic polycrystalline (Y-TZP) was developed to solve cracking and chipping problems in ceramic veneering made of opaque zirconia materials. They are also less translucent than glass-ceramics. Thus, the development of translucent Y-TZP to improve the translucency and colour of natural teeth was performed to overcome this constraint. [6] Zirconia with a high translucency has recently been produced for clinical usage. In order to improve Zirconia's translucency, impurities and residual pores that make volumes of different refractive indexes and cause optical scattering on the surface are removed for improving its translucency.[7] The optical characteristics of translucent materials can be influenced by interactions between light and translucent materials. When light passes through natural teeth, some of it is reflected, absorbed, and scattered, while the rest is diffusely transmitted. Materials have different microstructures, but the interaction of light with fine crystals can change their optical properties.[8] Transparency parameter (TP) was identified as the observed color difference in a material at a certain thickness.

A color difference existed between materials while in optical contact with a perfect black and white backing. The results of the translucency parameter and the color difference will be significantly influenced by the backings' reflectance values and the thickness of the translucent material.[9] Various factors including temperature, diet and humidity have to be taken into account when choosing an aesthetic restoration. These factors can change the translucency stability of recently introduced translucent zirconia materials and reinforced composite materials. [10] To enhance aesthetic result of restoration, it is fundamental to assess the impact of thickness on the translucency of high translucent (Y-TZP) zirconia and reinforced materials. However, data are limited about influence of artificial accelerated aging and thickness on translucency of both recent translucent zirconia materials and reinforced composite materials. Thus, the objective of this study is the assessment of the impact of artificial accelerated aging on the translucency of translucent yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) and reinforced composite with different thicknesses of both materials.

The null hypothesis of this study suggested that there would not be significant change in behaviour of translucency stability after subjected to aging for both CAD-CAM materials with different thicknesses.

Materials and Method

Specimens preparations:

Two different esthetic CAD/CAM materials were utilised in this study namely (reinforced CAD/CAM composite) and (3Y-TZP high translucent zirconia). A total 40 discs specimens were cut from each material (20 for each), which were cut into two subgroups in accordance with thickness (0.3mm and 0.5 mm). First, a ceramic cylinder with a diameter of 10 mm and a length of 14 mm was designed by CAD system software. composite blocks were mounted into a CAM milling machine (inlab MC XL milling system, Dentsply Sirona), milled into a cylinder designed according to the CAD system software (Inlab cad 19.2 digital software), and Zirconia HT blank mounted on the CAM milling machine. A machine (MC X5 milling machine, Dentsply Sirona) was used and milled.

A total forty discs were sectioned, twenty discs for each material which were obtained by using micro-saw (Isomet 4000 micro saw, Buehler, USA), with a diamond disk 20 cm in diameter and 0.6 mm-thick, running at a speed of 2500 rpm under cooling water irrigation system. Composite discs were cut into two different thicknesses (0.3mm and 0.5mm). The thickness of each composite disc was checked with a digital caliper (INSIZE, Jiangsu, China). All zirconia discs are sintered in a sintering furnace (inlab Profire, Dentsply Sirona) for 6 hours with a sintering program that gradually increases the temperature at a rate of 3 °C/min until reaching 1450 °C. Hold this temperature for 2 hours, then gradually reduce the temperature at 5 °C/min to complete cooling according to the manufacturer's instructions. A digital caliper was used to measure the final thickness of the disc after sintering. All composite discs were finished and polished with an Optra-Fine polisher (Optra-Finishing-Kit, Ivoclar Vivadent, Liechtenstein) consisting of a rubberized diamond-impregnated polisher, a high-gloss nylon brush, and a diamond-containing polishing paste. The Optra Fine Polisher is available in three different shapes for better access to all restoration surfaces. Polishing was performed using a low speed handpiece and an electric motor at speeds between 7000 and 10000 rpm, always using water cooling. A high flu overglaze was used for the Cercon glaze and

a staining and glazing oven (Multimat Cube Press, Dentsplay Sirona) was used according to manufacturing instructions. Finally, all samples were ultrasonically cleaned in an ethyl alcohol bath for 10 min using an ultrasonic cleaner (VS350; Silfradent), air-dried, packaged, and stored for optical transmission measurements.

Artificial accelerated aging:

Samples were autoclaved at 134 °C and 0.2 MPa for 5 hours in accordance with the International Organization for Standardization (ISO) 13356: 2015 standard which (aging treatment for 1 hour at 134 C with a pressure of 0.2 MPa has been reported to resemble effect of three to four years in the oral cavity. Each disc was put into a sterilization pack and after sealing the sterilization pack, the sample was put into an autoclave (Clear Autoclave, Class B, made in China).(Figure 1) 5 hours were equalled (10 cycles), which the autoclave cycle started from zero pressure and increased to the desired pressure (2 bars) in 15 minutes, so the autoclave cycle (45 minutes) was calculated only as 30 minutes.

Figure (1) sterilization pack labeled with the ceramic material type, thickness, and specimen numbers were placed in autoclave

Translucency evaluation:

Translucency values for all samples were measured from one surface before aging, the polished side for zirconia samples, and the polished side for resin-based ceramic samples. on a CIELAB color space spectrophotometer (Cary 5000, Agilent Technologies, USA) under D65 illumination. After aging, all samples were subjected to spectrophotometric analysis to detect optical translucency parameters for each material type and different thicknesses. Measurements were made using a spectro-photometer on white and black backgrounds and average values of CIE L*a*b* were registered for both backgrounds. The calculation of of the color difference between white and black background samples using the following formula was performed to determine the translucency parameter (TP):

Translucency Parameter (TP) = [(LB*-LW*)2+(aB*-aW*)2+(bB*-bW*)2]1\2

In this formula, B means color coordinates on a black background and W means color coordinates on a white background. The higher the value of TP, the higher the light transmittance of the material, post-aging (TPs) values were measured, and the TP values were statistically compared with the measured TP values before aging.

Statistical analysis

A repeated measures ANOVA test was utilised to examine the effects of materials, thickness, aging protocol, and their interaction on the permeability parameter (TP). Test of Bonferroni's post hoc was utilised for pairwise comparisons in case the ANOVA test was significant, test was used for pairwise comparisons. The level of significance was determined at $P \leq 0.05$. The performance of statistical analysis was carried out using IBM SPSS Statistics for Windows version 23.0. Armonk, New York:

Results

Impact of material regardless of thickness, and aging, reinforced CAD-CAM composite revealed statistically significantly greater mean TP than Zirconia (P-value <0.001). Generally, 0.3 mm revealed statistically significantly greater mean TP than 0.5 mm thickness (P-value <0.001). With reinforced CAD-CAM composite 0.3, 0.5 mm thicknesses and with Zirconia HT 0.3, 0.5 mm thicknesses, a statistically significant decline in mean TP after aging was existing (Figure 2).

Table (1): Comparison of translucency parameter (TP) results (Mean±SD) between both groups before and after artificial aging

Material	Aging protocol	Thickness	Before aging		After aging		*P*-value
			Mean	SD	Mean	SD	
Reinforced composite	Accelerated aging	0.3 mm	25.16	0.09	22.55	0.13	<0.001*
		0.5 mm	18.8	0.11	16.95	0.15	<0.001*
Zirconia HT	Accelerated aging	0.3 mm	14.79	0.13	13.28	0.16	<0.001*
		0.5 mm	11.46	0.12	10.30	0.13	<0.001*

*: Significant at P ≤ 0.05.

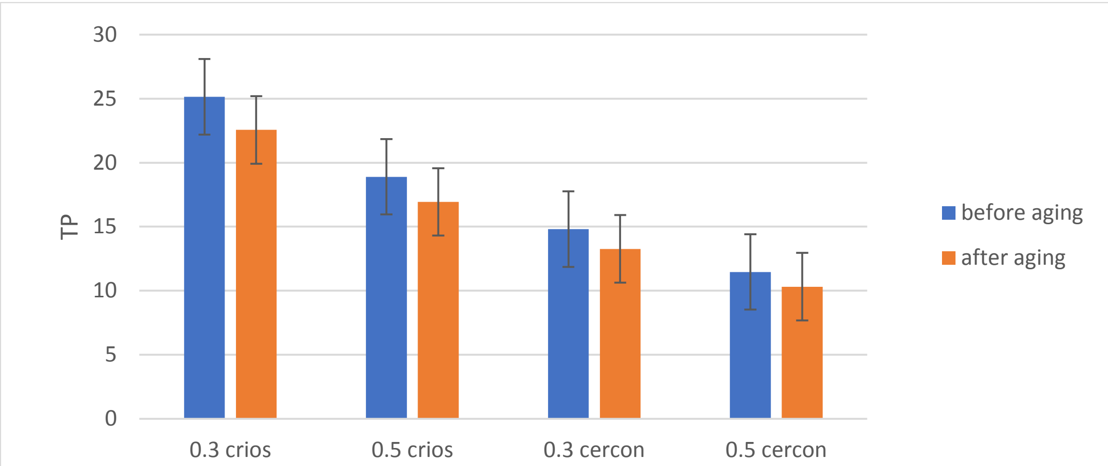

Figure (2) Bar chart representing mean and standard deviation values for TP before and after aging with different interactions of variables.

Discussion

The demand for aesthetic and restorative requirements in prosthetic dentistry has led to the development of several treatment options. Laminate veneer restorations are gaining popularity as a more aesthetic and conservative solution.[11] Different thickness monolithic materials of CAD-CAM tested in the current study were chosen to mimic laminate veneers. Fixed prostheses are vulnerable to the chemical, moisture, and temperature cycles of the oral environment. Therefore, in vitro studies with artificial aging processes should simulate similar conditions to draw accurate conclusions about durability and aesthetic long-term behavior. In this study, hydrothermal aging which represent a method of low temperature degradation including placement specimens in autoclave at 134°C and 0.2 MPa for a duration of 5 hours in accordance with the International Organization for Standardization (ISO) 13356: 2015 standard [12] where (aging treatment for 1 hour at 134°C with a pressure of 0.2 MPa has been recorded to resemble effect of three to four years in the oral cavity at 37°C), so 5 hours resemble 15–20 years in an oral environment at 37C.

In this study, it was found that reinforced CAD-CAM composite showed statistically significantly higher mean TP than Zirconia. This may be due to the different composition of the microstructures. Zirconia's opacity can be explained by the presence of defects, impurities, and alumina segregation at grain boundaries, which are the most common reasons for zirconia's opacity. This increases surface scattering and refraction rather than transmitting light. [13,14] previous studies by Awad et al., [15] and researchers [24–26] supported the current results. They reported that zirconia is more opaque than other types of ceramics, and the translucency of dental ceramics relies on several factors including crystal structure, grain size, pigment, number of defects, size, distribution, and porosity.

The outcomes of this study show that the thickness has a remarkable effect on the translucency parameter. In general, 0.3 mm thickness was significantly more translucent than 0.5 mm thickness, regardless of material type. Explanation behind this can be demonstrated considering the fact that the thicker the material, the higher the scattering of light, the higher the refractive index that light must pass through, and the lower the light transmission. Earlier studies of Al-Juaila et al.,[19] and Olcay et al.,[20] showed that the thickness of ceramic restorations was the primary factor influencing translucency. When a ray of light goes through a material, crystals inside the microstructure of the material impede the light's path, causing deflection of the light ray enhancing scattering. Since more crystal structure increases scattering and decreases light transmission, it appears to be less translucent, so thinner thickness has the fewest number of crystals or filler particles and reduces light scattering. Decrease.

In this study, an artificially accelerated aging process was utilised to investigate the impacts of accelerated aging on CAD/CAM ceramics. We found that autoclave aging resulted in a statistically significant decline in values of TP for both aesthetic ceramic materials.

According to the outcomes of this study, the decrease in TP values of the artificial accelerated-aged zirconia samples (0.3 and 0.5 mm) was attributed to a gradual spontaneous transition from the metastable tetragonal phase to the monoclinic phase (t-m transition) in the existence of water vapor or water at relatively low temperatures (almost 30°C to 400°C) [21]. This phenomenon is called hydrothermal degradation or low temperature degradation, and progresses gradually from the surface of the ceramic to the inner surface.[22] Micro- and macro-cracks can then occur because of the volume expansion that occurs. This can act as a porosity or defect that increases scattering of the incident light beam and reduces light transmission[23,24]. These ultimately leads to in accordance with Koseoglu et al., [1] who reported that the TP value of monolithic zirconia samples decreased after the hydrothermal aging process, which made the zirconia material more opaque. On the contrary, Abdelbary et al.,[5] reported that the translucency of zirconia was unaffected by hydrothermal aging.

The decrease in TP values of accelerating aged reinforced CAD-CAM composite samples (0.3 and 0.5 mm) are likely due to the combined effect of moisturization, humidity and thermal changes. Moisture can lead to increased water absorption in the resin material structure, especially in the presence of hydrophilic cross-linking monomers (Bi-GMA, TEGDMA), leading to expansion of the polymer network and degradation in the coupling agent between polymer and fillers, lead to deterioration of Roughness remains on the surface, which adversely affects light transmission. Due to the different coefficients of thermal expansion of the particles of the filler and the resin matrix, thermal changes can lead to induction of internal stresses in the material, leading to cracks and voids that act as scattering indices that reduce light transmittance. [25] These results are consistent with Arif et al.,[16] concluded that the related material translucency parameter of the currently investigated material decreased after thermocycling of coffee. On the other hand, Porojan et al.,[26] reported that the translucency parameter of the resin cad-cam material, which is related to the material under study, is largely unaffected by thermocycling.

The results of this study have been controversial among previous researchers. This may be due to different sample thicknesses or different aging protocols to which the samples were exposed, and several factors such as ceramic brand, ceramic thickness, grain size and sintering parameters may affect the light transmittance may be affected. Yttria content and surface condition. In general, translucency proved to be a highly sensitive parameter influenced by all other variables investigated in the current study. The interaction between variables, type of the ceramic material, thickness and aging protocol were significant.

Based on the results of the previous study and discussion, the null hypothesis was rejected. After artificial accelerated aging, there were significant differences and variations in the translucency parameters of the two aesthetic CAD-CAM materials with two different thicknesses.

Conclusion

Within the limitation of this study, we can draw the following conclusions:

1. For all materials, translucency parameter increased with decreasing thickness, however this effect varied by both brand of material and thickness.
2. Thickness had a statistically significant impact on translucency parameter which translucency decreased by increasing the thickness for both materials
3. Artificial accelerated aging had a statistically significant decline in mean TP following aging for both materials and both thicknesses.

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